

MiniBooNE Neutrinos at MINOS

D. Bogert, P. Shanahan, W. Smart
Fermilab

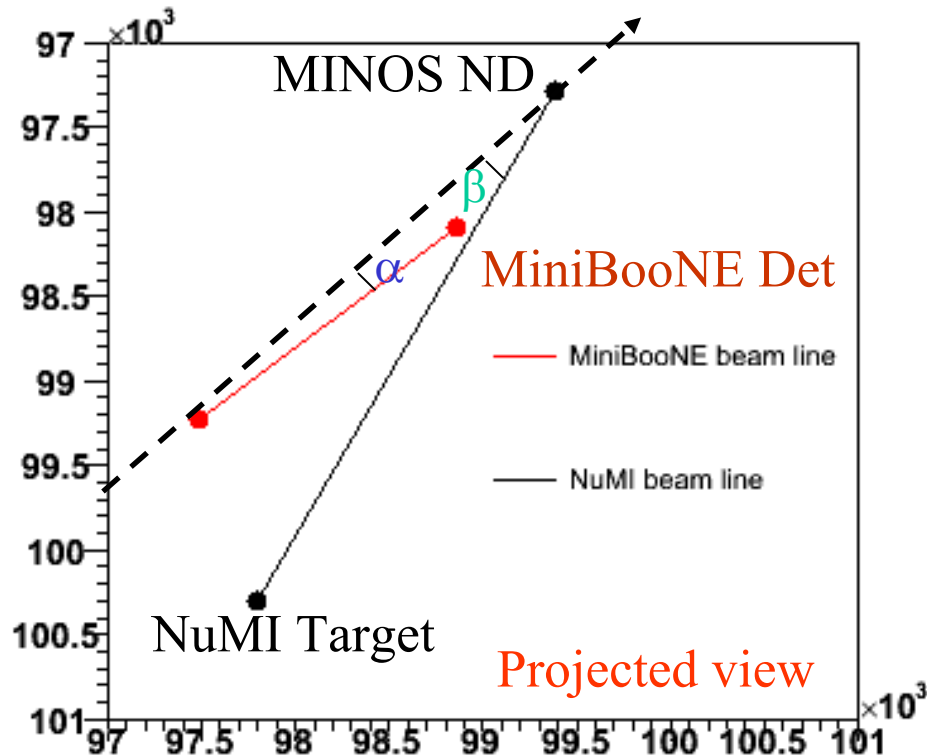
H. J. Kang, S. Murgia, T. Yang, S. Wojcicki
Stanford University

Fermilab All Experimenters' Meeting

Feb 13, 2006

Geometry

NuMI and MiniBooNE beam lines



α : off-axis angle to the MINOS detector = 9.13 deg

β : incident angle of MiniBooNE neutrinos on MINOS ND = 16.9 deg

Incoming direction of MB neutrinos:

zenith: 83.5 deg

azimuth: 172.8 deg

Kinematics

- Two-body decay in Lab frame:

$$E_\nu = \gamma \frac{M^2 - m^2}{2M} (1 + \beta \cos \theta)$$

E_ν : ν energy in Lab frame

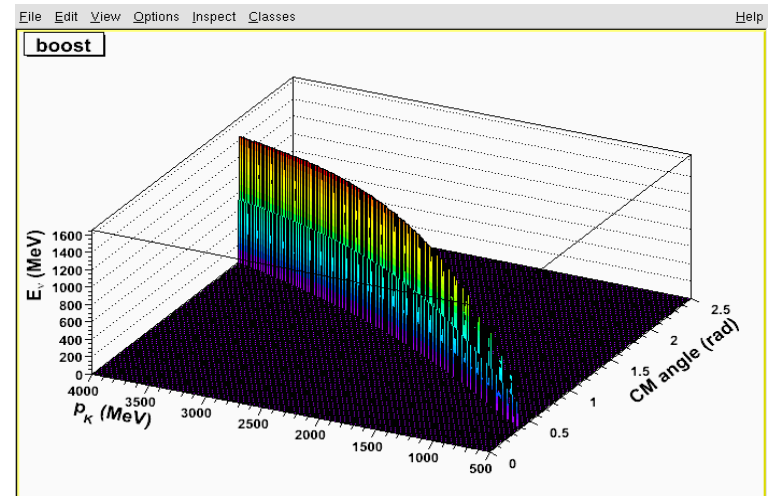
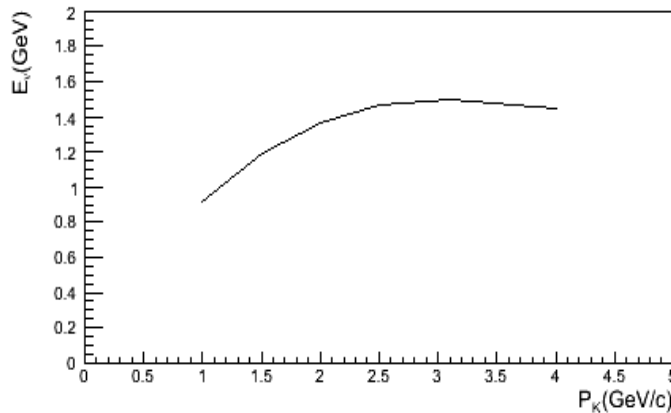
$$\tan \alpha = \frac{\sin \theta}{\gamma(\cos \theta + \beta)}$$

α : ν angle in Lab frame

M: pion or kaon mass, m: muon mass, θ : ν angle in the CM frame

- For $\alpha = 159 \pm 1.2$ mrad (9.13 deg), get highly monochromatic ν beam

Neutrino energy from kaon decay



- Max E_ν : 1.5 GeV for K, 189 MeV for π
- ν from π decays hard to separate from noise

What can we do with MB ν 's?

➤ Highly monoenergetic ν beam:

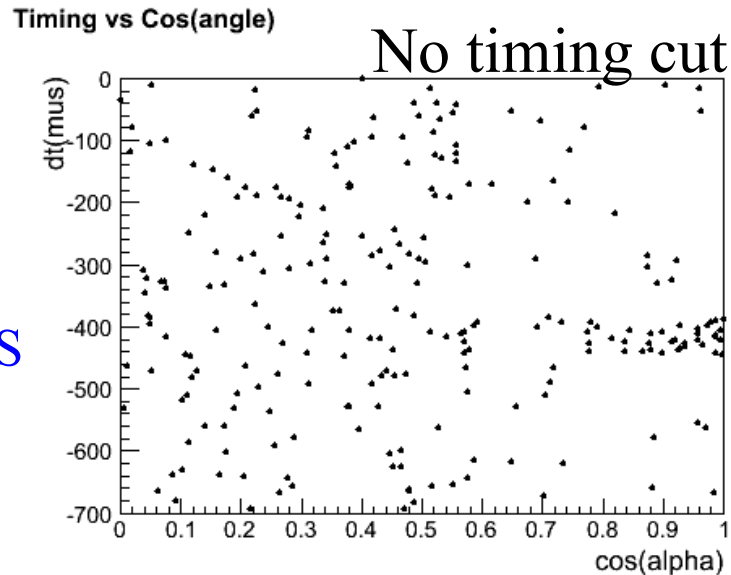
- Determine the energy scale
- Better signal/background discrimination for ν_e
- Study cross sections for different interaction channels
- Anomalous ν_e production

➤ For now, ν_μ CC only

Selection

- Search for MB neutrinos in MINOS ND cosmics data stream:
between NuMI spills, data is recorded if at least 10 planes have a hit above $\sim 1/3$ pe.
(4 out of 5 consecutive planes as of Dec 05)
- Aug, Sep, Oct 05 MINOS ND data has been processed so far
- Select events with:
 - At least a track with contained vertex
(within 1 m radius around beam direction and 0.5 m to 6 m into detector)

dt = Difference between
MB spill and MINOS
ND timestamp
 α = angle between track
and MB target to MINOS
ND direction



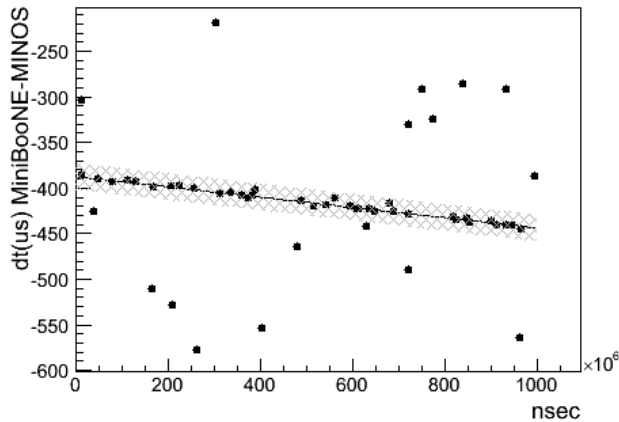
MB events

→ Wide dt distribution

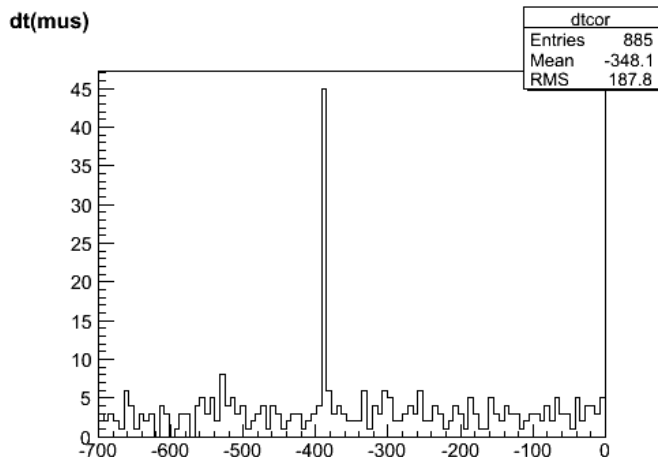
Thanks to Steve Brice for providing the MiniBooNE spill timestamps (ACNET)

Selection - contd

- Clean up the sample by selecting tracks loosely pointing back to the MiniBooNE target ($\cos(\alpha) > 0.6$)
- Correct for difference in nsec counting between MB and MINOS:

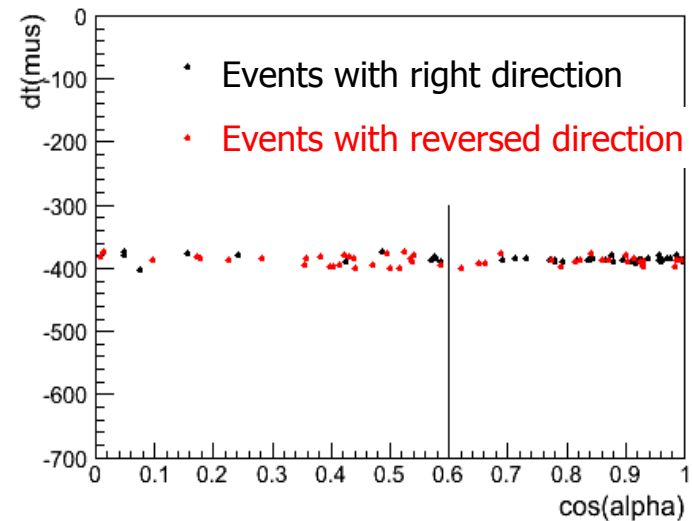


- Narrower dt distribution after correcting for time mismatch:



With timing cut ($\pm 15 \mu s$):

Timing vs Cos(angle)



Event 1.

File Pages Views Settings Zoom

<-Jump->

RunNin:

RunNpass:

RunNfail:

Run:

Snarl:

Next -->

UserCanvas | UserCanvas | UserCanvas | UserCanvas | UserCanvas | UserCanvas

<-- Prev

NextPass -->

Free Running

0

Next Event

Prev Event

Event: 0(1)

0

Cuts: OFF

Write

NextSelEvt

PrevSelEvt

MC Truth

Fix MC Info

Strip vs. Plane, U view

Run: 8363/4, Snarl: 204754, Event: 0(1)

Reco:

ntrks: 1 nshws: 1 zenith: 65.1 azimuth: 184.3
 trk.range:1.02GeV, fit:-0.99GeV, qp:-1.005
 trk.pls:20, length:1.6m, like:17, eqp:0.09
 shw.gev:1.82GeV, linCC:2.35GeV, pls:10

Strip vs. Plane, V view

Initial State

Intermediate

Final State

Later Decays

| | | | |
|--------|-------------|--|---|
| mu | QE | Comments? -425.026us | Run: 8363/4, Snarl: 204754, Event: 0(1) Reco Info ntrks: 1 nshws: 1 zenith: 65.1 azimuth: 184.3 trk.range:1.02GeV, fit:-0.99GeV, qp:-1.005 trk.pls:20, length:1.6m, like:17, eqp:0.09 shw.gev:1.82GeV, linCC:2.35GeV, pls:10 Pre-selection: Fail Fid: Pass Trk: Fail Trklike: Pass Shw: Pass E: Pass |
| e | RES | File to Open? | |
| NC | DIS | TYPE <input type="checkbox"/> mu <input type="checkbox"/> e <input type="checkbox"/> NC <input type="checkbox"/> mu/NC? <input type="checkbox"/> e/NC? <input type="checkbox"/> ??? <input type="checkbox"/> N/A TOPOLOGY <input type="checkbox"/> QE <input type="checkbox"/> RES <input type="checkbox"/> DIS <input type="checkbox"/> ??? <input type="checkbox"/> N/A | |
| mu/NC? | ??? | | |
| e/NC? | N/A N/A | | |
| ??? | Log Details | | |

Next Event

Prev Event

Event 2.

File Pages Views Settings Zoom

<-Jump->
RunNin:
RunNpass:
RunNfail:
Run: 8695
Snarl: 583110

Next -->
UserCanvas
UserCanvas
UserCanvas
UserCanvas
UserCanvas
UserCanvas

<-- Prev
NextPass -->
Free Running
0
Next Event
Prev Event
Event: 0(1)
0
Cuts: OFF
Write
NextSelEvt
PrevSelEvt
MC Truth
Fix MC Info

Strip vs. Plane, U view

Strip vs. Plane, V view

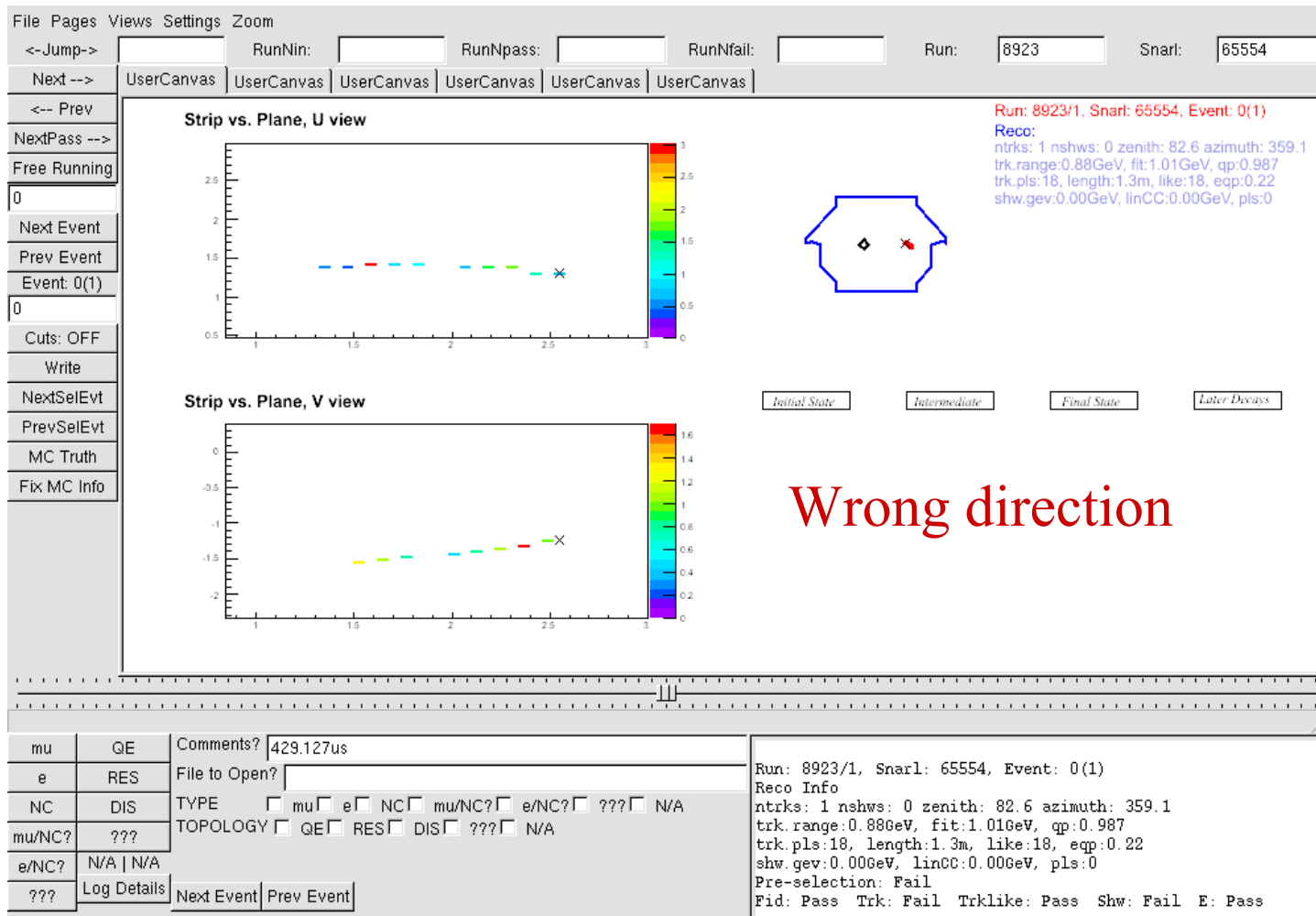
Initial State
Intermediate
Final State
Later Decays

Run: 8695/12, Snarl: 583110, Event: 0(1)
Reco:
ntrks: 1 nshws: 1 zenith: 86.4 azimuth: 175.7
trk.range:0.94GeV, fit:-1.44GeV, qp:-0.693
trk.pls:21, length:1.4m, like:21, eqp:0.20
shw.gev:0.12GeV, linCC:0.10GeV, pls:3

| | | | |
|--------|-------------|---------------|---|
| mu | QE | Comments? | 422.167us |
| e | RES | File to Open? | |
| NC | DIS | TYPE | <input type="checkbox"/> mu <input type="checkbox"/> e <input type="checkbox"/> NC <input type="checkbox"/> mu/NC? <input type="checkbox"/> e/NC? <input type="checkbox"/> ??? <input type="checkbox"/> N/A |
| mu/NC? | ??? | TOPOLOGY | <input type="checkbox"/> QE <input type="checkbox"/> RES <input type="checkbox"/> DIS <input type="checkbox"/> ??? <input type="checkbox"/> N/A |
| e/NC? | N/A N/A | | |
| ??? | Log Details | Next Event | Prev Event |

Run: 8695/12, Snarl: 583110, Event: 0(1)
Reco Info
ntrks: 1 nshws: 1 zenith: 86.4 azimuth: 175.7
trk.range:0.94GeV, fit:-1.44GeV, qp:-0.693
trk.pls:21, length:1.4m, like:21, eqp:0.20
shw.gev:0.12GeV, linCC:0.10GeV, pls:3
Pre-selection: Fail
Fid: Pass Trk: Fail Trklike: Pass Shw: Fail E: Pass

Event 3.



- Although the track appears to be coming from the North (MB v are from the South), the timing of this event is consistent with the MB spill.
- This type of event is classified as a MB v. Studies to improve the direction finding algorithm are ongoing.

Event 4.

File Pages Views Settings Zoom

<- Jump ->

RunNin:

RunNpass:

RunNfail:

Run: 8920

Snarl: 280956

Next -->

UserCanvas UserCanvas UserCanvas UserCanvas UserCanvas UserCanvas

<-- Prev

NextPass -->

Free Running

0

Next Event

Prev Event

Event: 0(1)

0

Cuts: OFF

Write

NextSelEvt

PrevSelEvt

MC Truth

Fix MC Info

Strip vs. Plane, U view

Strip vs. Plane, V view

Initial State Intermediate Final State Later Decays

Run: 8920, Snarl: 280956, Event: 0(1)

Reco:

ntrks: 1 nshws: 1

E_{trk}: 2.16GeV, trk length: 32, trk like: 32

E_{shw}: 0.00GeV, shw length: 0

| | | |
|--------|-------------|--|
| mu | QE | Comments? |
| e | RES | File to Open? |
| NC | DIS | TYPE <input type="checkbox"/> mu <input type="checkbox"/> e <input type="checkbox"/> NC <input type="checkbox"/> mu/NC? <input type="checkbox"/> e/NC? <input type="checkbox"/> ??? <input type="checkbox"/> N/A |
| mu/NC? | ??? | TOPOLOGY <input type="checkbox"/> QE <input type="checkbox"/> RES <input type="checkbox"/> DIS <input type="checkbox"/> ??? <input type="checkbox"/> N/A |
| e/NC? | N/A N/A | |
| ??? | Log Details | Next Event Prev Event |

Run: 8920, Snarl: 280956, Event: 0(1)

Reco Info

ntrks: 1 nshws: 1

E_{trk}: 2.16GeV, trk length: 32, trk like: 32

E_{shw}: 0.00GeV, shw length: 0

Pre-selection: Fail

Fid: Pass Trk: Fail Trklike: Pass Shw: Fail E: Pass

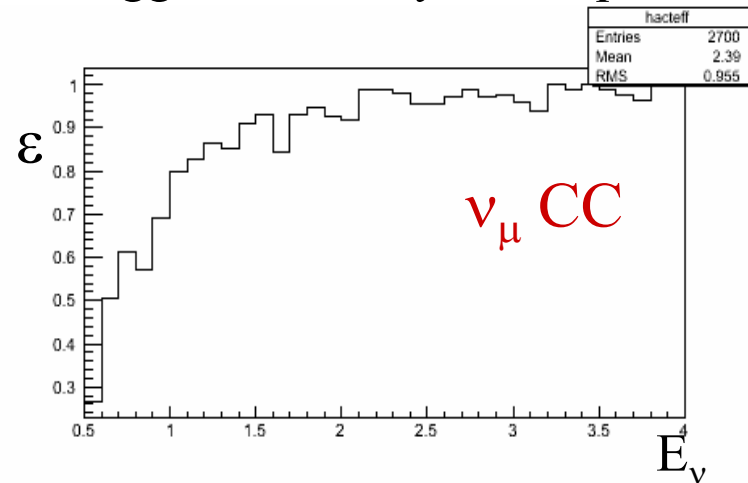
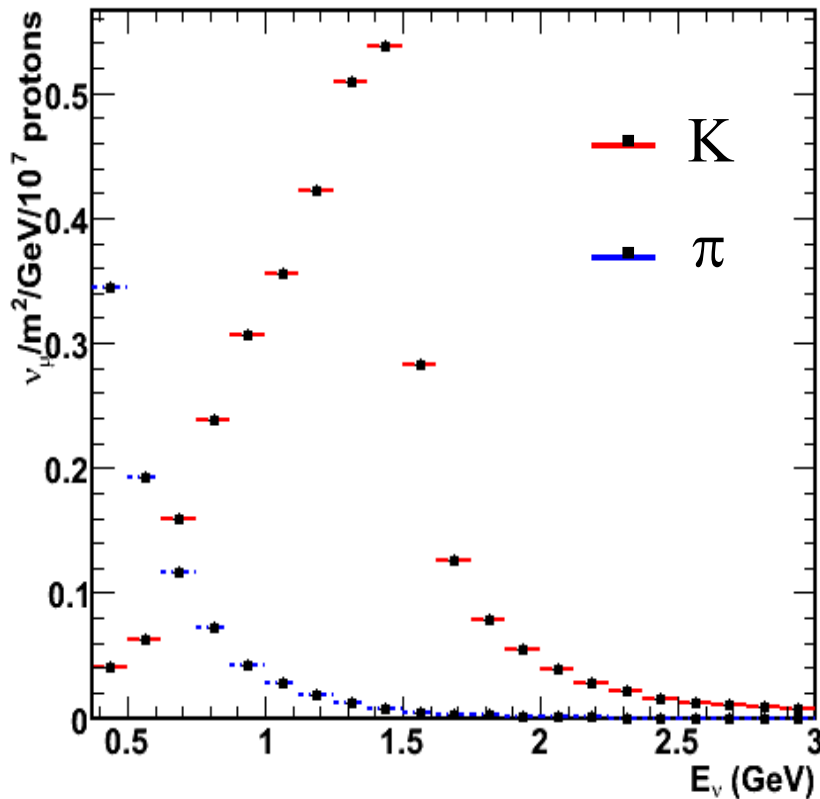
Likely cosmic background

MC Simulation

- PBEAM simulation of ν_μ flux from MB target at ND:

- ν_μ (NC and CC) and ν_e interactions in the MINOS ND are simulated assuming the incoming MB direction.
- Events are generated with energy between 0.1 GeV and 4 GeV and weighted with the PBEAM flux.
- The MC is normalized to the MB POT and has to pass the online trigger requirement and offline selection as the data.
- MC trigger efficiency for 10 planes activity:

FLUX from K+ vs NU ENERGY (GeV), Z= 51.+768. m



MC – Data Comparison

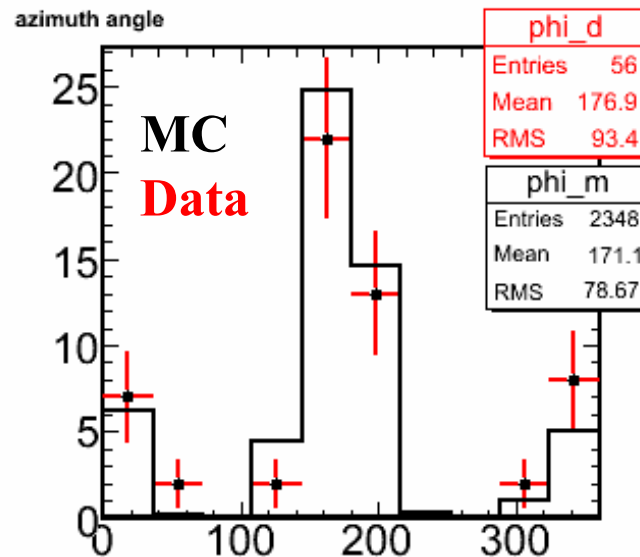
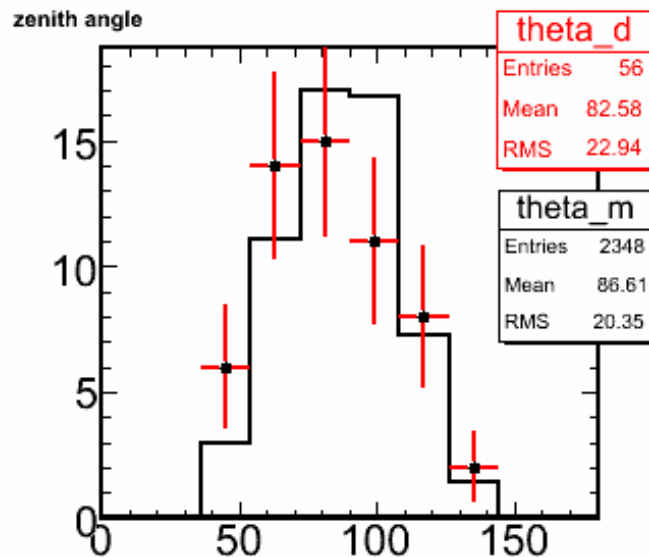
➤ Event rate for ν_μ CC for 3 months:

Data: 56

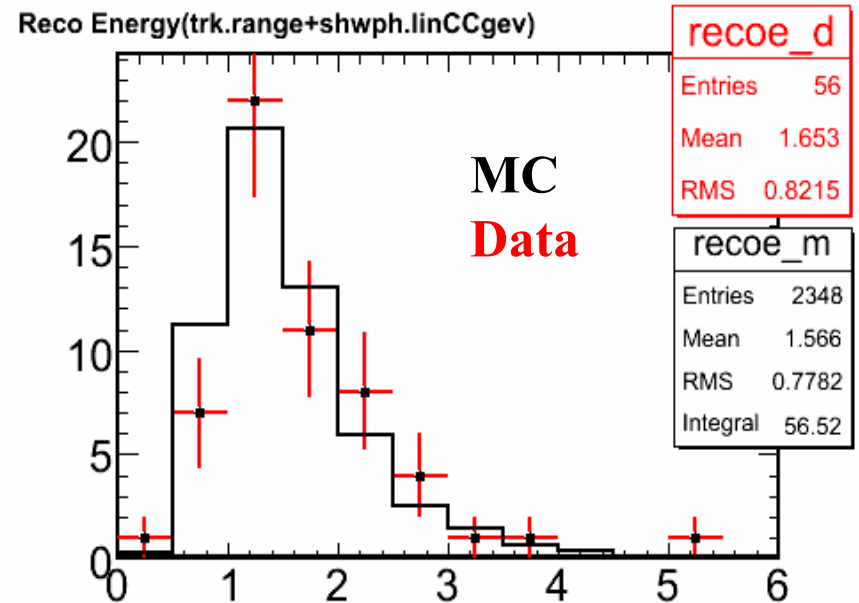
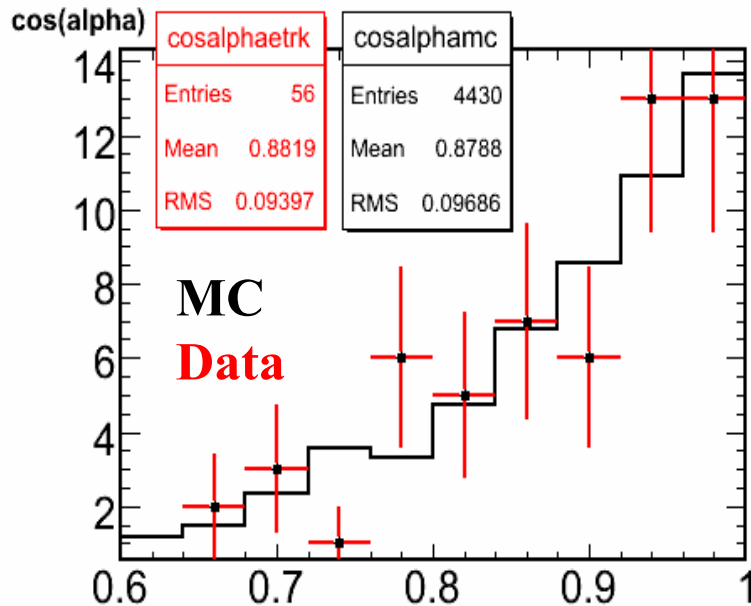
MC: 56.5

➤ No background subtraction in data!
Under study.

| Rates (data) | Aug | Sep | Oct |
|--------------|------|-----|------|
| POT (E19) | 1.75 | 1.5 | 2.76 |
| ν_μ CC | 15 | 12 | 29 |



MC – Data Comparison



- Good agreement between data and MC angular distributions
- Need more statistics

Conclusions/Ongoing work

- We have searched for MiniBooNE neutrinos in the MINOS ND
- By applying loose track direction, containment requirements and timing consistent with the MiniBooNE spills, we find **56 ν_μ CC** candidates for 3 months (Aug-Oct 05) of data taking, in good agreement with the MC prediction of 56.5 events.
- We are processing the remaining data from 2005.
- We plan to improve the flux modeling by including the MiniBooNE beam fluxes instead of PBEAM (PBEAM flux $\sim 30\%$ larger)
- We are working on improving the direction finding algorithm and cosmic background rejection.
- Hardware to trigger the ND readout on the MiniBooNE spill signal is under development.